ENGINEERING FEASIBILITY REPORT

BIND

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U.S. BICENTENNIAL WORLD EXPOSITION, BOSTON

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May 1969

Prepared by the U. S. Bicentennial World Exposition Corporation Staff from studies prepared by the Urban Systems Laboratory of The Massachusetts Institute of Technology.

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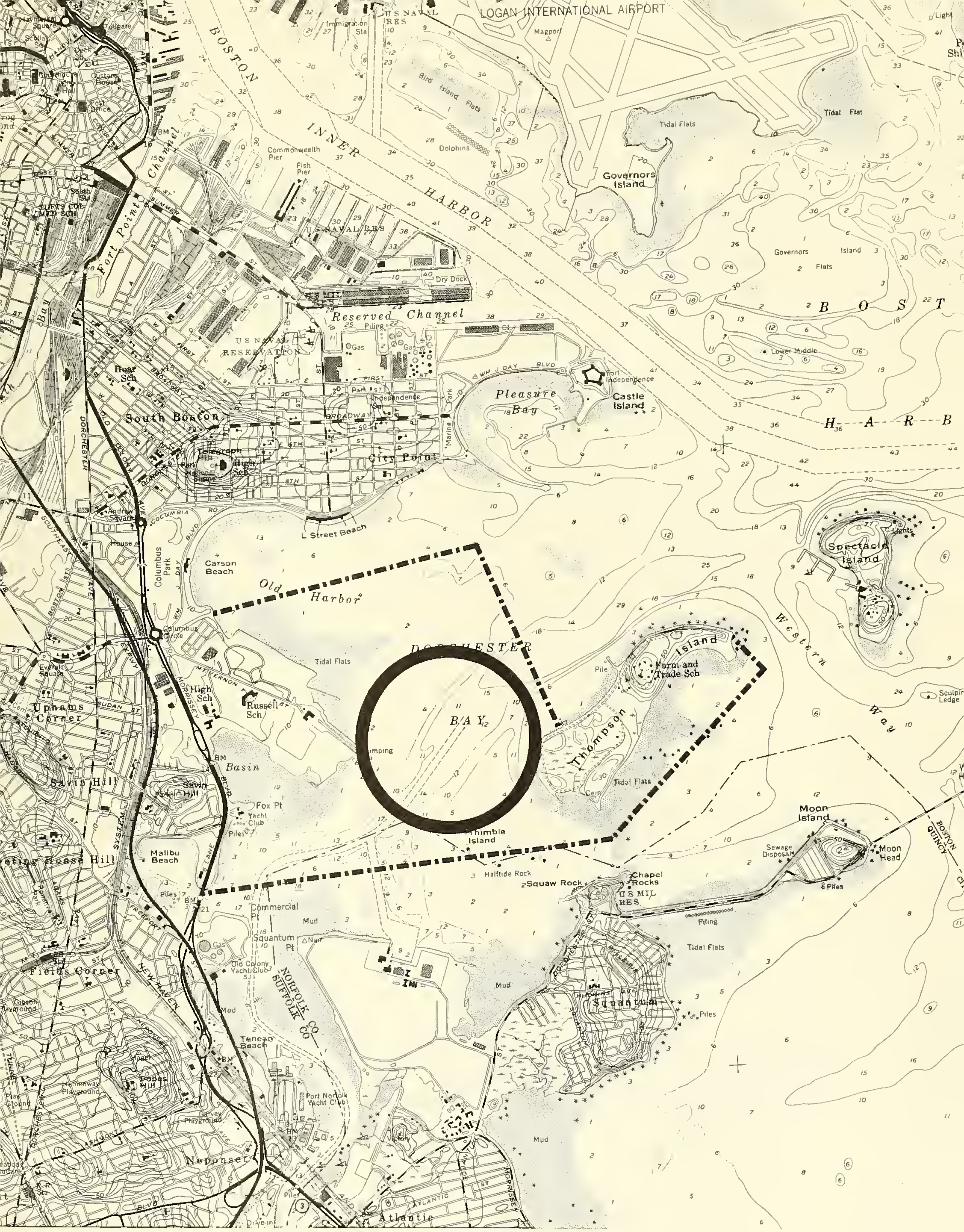
INTRODUCTION

The Urban Systems Laboratory at M.I.T. as part of their comprehensive studies of Dorchester Bay prepared over 300 pages of loose-leaf reports and memoranda. During the course of their studies they held meetings with BRA staff, Expo Boston staff and officials of the various city, state, federal and authority agencies directly concerned with various aspects of development (for example: the U.S. Army Corps of Engineers, the M.D.C., and the Harbor Islands Commission). This report has been prepared by the Expo Boston staff, based upon information supplied in the engineering portions of those studies.

Since the site to be developed is in part over water, the characteristics of the bottom are vitally important to the type and cost of construction. This report discusses the underlying geology of the site, the various kinds of feasible foundation techniques and the implication of Expo construction for the harbor, in its presently polluted condition. Available evidence indicates that proposals for site construction and associated engineering improvements are technically feasible and will not adversely affect tidal flow. No evidence has been found indicating that this development will prove harmful to the ecology of Dorchester Bay or Boston Harbor. On the contrary, one goal of Expo Boston is to improve the quality of Dorchester Bay and to end the gross water pollution that presently contaminates the Bay. Upon designation as host for the U.S. Bicentennial, Expo Boston will continue to cooperate with others interested in Harbor quality in the preparation of detailed ecological and pollution studies. This report also examines air noise as it affects the site and concludes that this will not preclude development.

The cost estimates and other findings of this report have been used by the BRA designers in refining their plan and by the Expo staff and the Arthur D. Little Company with the assistance of the construction economists of Hanscomb Roy Associates of Montreal, in preparing the Expo budget estimates.



SITE LOCATION

AREA OF SEISMIC INVESTIGATION

Engineering Geology

Foundations engineers are concerned with four basic parameters: the depth to the bedrock surface, the strength of this rock, the type and thickness of the sediments overlying bedrock, and the compressibility of these sediments.

The depth to the upper surface of bedrock can be very important in determining the cost and nature of building foundations. If the bedrock is shallow, buildings may be supported on short piles resting on or in the rock. If, however, the bedrock surface is quite deep, the cost of driving piles to bedrock may be prohibitive; in such cases the engineers turn to other means of support, such as friction piles in clay, or displacement foundations. In the latter case, a volume of soil approximately equal to the total weight of the building is excavated, and a basement constructed. This type of foundation has been used quite successfully in the Boston area.

The Boston Basin

A large portion of Eastern Massachusetts was at one time a vast lake. This area, now known as the Boston Basin, includes much of greater Boston and the Massachusetts Bay This lake has had a profound affect on the geology of the area, particularly the materials overlying bedrock.

Bedrock

Most of Boston Harbor is underlain by a sedimentary rock known as the Cambridge argillite (also known as the Cambridge slate or Cambridge siltstone). This rock is derived from

fine-grained muds which were consolidated under great pressure for long periods of time. It is generally strong enough to support heavily loaded piles or piers that might be used to support buildings (even taller than the 10 to 12 stories contemplated on the site). There are, however, local "soft" zones the occurrence of which is unpredictable and which are not strong enough to support heavily loaded piles and piers. In some areas, the Cambridge argillite has been eroded away, exposing the Roxbury conglomerate or the Squantum tillite. (These are sedimentary rocks composed of small pebbles or cobbles of other rocks which have been cemented together by consolidated mud or clay.) The Squantum tillite is considered a "soft" rock, but both the conglomerate and tillite will support moderately tall buildings.

Till

The entire Boston Basin has been covered by glaciers several times. As a result, much of the bedrock is covered by a layer of glacial till. Till, or "hardpan," is a mixture of boulders and rock debris left behind by the glaciers. The till itself is frequently strong enough to support building foundations. In these cases the depth to till is more significant than the depth to actual rock.

Drumlins

Many of the Harbor islands are local mounds of till known as drumlins left by a glacier. They are often strong enough to support heavy foundations. In addition, many of the drumlins are reinforced by rock cores, either bedrock or intrusive dykes or ledges. The northern half of Thompson Island (that portion occupied by Thompson Academy) is such a drumlin. (This drumlin does not extend into the southern half of the Island.)

Bedrock contours have been analyzed based upon the results of borings and geophysical surveys. The primary sources of this information are: 1) the Boston Society of Civil Engineers handbook--Boring Data for Greater Boston, (1961), 2) the Columbia Point Sub-soil and Site Condition Study (1964), 3) plans of MDC sewers, 4) a seismic survey done by Weston Geophysical Engineers for Boston Edison Co., and 5) the seismic investigations done by Weston Geophysical Engineers for the BRA in conjunction with the present project.

Subsoils

The most prominent sedimentary feature of the Boston Basin is a vast deposit of soft clay known as the "Boston blue clay". The upper layer of the blue clay has been oxidized to form a generally firmer yellowish clay, referred to by Boston engineers as the "stiff crust" which has bearing capacity. This clay underlies much of Boston, not just Dorchester Bay. Some of the city's tallest buildings are built on it. The thickness of this clay varies from 0 feet to over 200 feet; its upper surface is quite irregular, showing a relief of over 100 feet within the Harbor. The clay was generally deposited in the still waters of the lake, and is thus a very fine-grained deposit. However, it also contains some lenses of silt, sand, and gravel.

Above the yellow clay lies a thin (5 feet to 10 feet in most places) layer of fine silt, and a thicker layer of black, organic mud. This mud has a high carbon content, generally attributed to sewer outfalls in or near the Harbor. (Mencher, Copeland, and Payson, 1968). It is highly compressible and will not support structures or landfill.

The southern half of Thompson Island is a gravel outwash which extends at least to the mouth of the Neponset River. The surficial deposits surrounding Thompson Island are mostly

mud with some sand and gravel. The thickest mud beds in Dorchester Bay occur just west of Thompson Island, in the channel adjacent to the Island (from the Neponset River). Carson Beach and parts of the Old Harbor have sandy bottoms, apparently underlain by thick beds of soft clay. Columbia Point consists largely of fill contained by rock rip rap and surrounded by mudflats.

Foundation Types

In general, there are four types of foundations in common use: 1) displacement, or "mat" foundations, 2) pile foundations, 3) caissons, and 4) spread footings. The soils in the vicinity of the site are not firm enough to support major building with spread footings so it will not be discussed further.

Displacement foundations require the excavation of a volume of soil approximately equal to the total weight of the building to be supported, and a basement to fill the excavation. To prevent damage from unequal settling, the building is built on a thick (several feet) mat of reinforced concrete resting on a bed of sand or gravel. This type of foundation has been used quite extensively and successfully in the Boston area.

Piles are the most common foundations for large buildings. Piles are made of steel, concrete, wood, or a combination of these materials. Piles may rest on or in rock, till, sand or hard clay strata, or they may be friction piles driven into the soil. The cost of piles is a function of the length of the piles and the load they support. (However, the cost of piles rises sharply for lengths greater than about 150 feet).

Caissons are large (at least four feet in diameter) piles in which a column is first excavated in the soil then filled with concrete. They usually rest on or in rock or till and frequently have flares, or "bells", at the lower end to help transfer their load to the bearing stratum. Caissons are generally expensive, due to the difficult excavation required, but because of their large cross section, caissons are capable of supporting extremely large loads, and are therefore used where this characteristic is needed. They are not usually used in saturated or porous soils such as those found on the site because of the difficulty of excavating in such conditions. They will therefore not be discussed further.

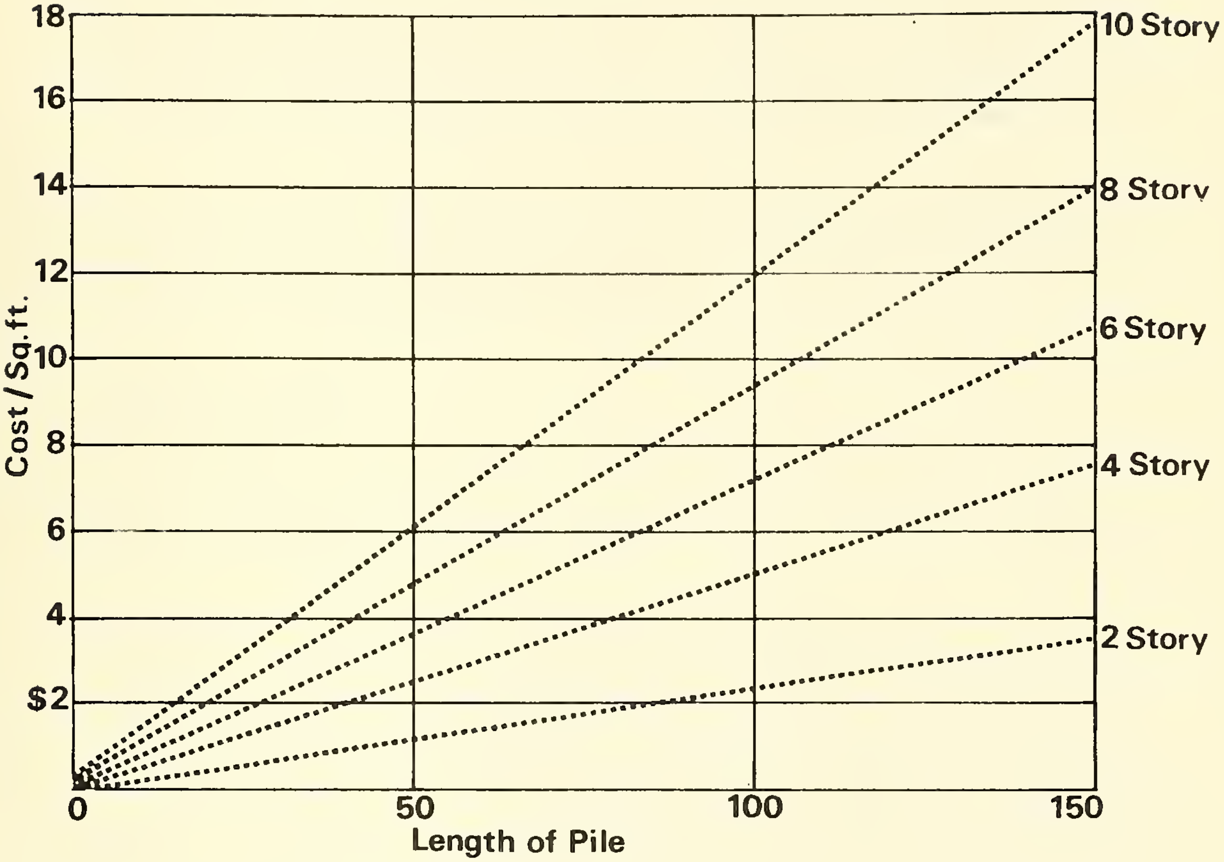
Costs of Foundations

The accompanying figure shows the foundation cost (per square foot) for displacement foundations and pile foundations. A dead load of 150 psf per floor is assumed, and a live load of 50 psf for residential buildings and 150 psf for exhibition buildings (per floor). In preparing this figure, piling cost was computed at ten cents for each foot of pile length, times the number of tons of load; reinforced concrete cost was taken as 65 cents a cubic yard; and an excavation cost of $5.50 a cubic yard was used.

The displacement foundation will require a mat about six inches thick per floor (counting basement) and be located in areas where the material excavated has a density comparable to that of Boston blue clay.

To obtain approximate costs of foundations, multiply the unit costs from the table by the exterior dimensions (length and width) of the building. (Individual buildings of course may present unusual conditions which might raise or lower these costs.)

COST OF PILE FOUNDATIONS



COST OF DISPLACEMENT FOUNDATIONS*

2 Story	$3.40/sq.ft.
4 Story	$6.60/sq.ft.
6 Story	$9.90/sq.ft.
8 Story	$13.30/sq.ft.
10 Story	$16.60/sq.ft.

* Independent of depth of bedrock

Both types of foundations may be designed to support buildings up to 10-15 stories with very little settlement. Generally, the displacement foundation provides better support for utilities. However, the displacement foundation requires excavation for and waterproofing of, a basement, adding to the structural cost of the building (but providing additional floor space, if desired).

The cost of pile foundations is dependent upon length of the piles. The depth to bedrock in the water areas of the site ranges from 20' to 150'.

Landfill Types

Historically, Boston has always known the advantages of making new land by fill. Almost 80% of the city is the result of filling water areas.

The types of fill most feasible for use in Boston Harbor are clay, dredged from the Harbor bottom and placed hydraulically, or granular material (sand and gravel), either dredged from near-shore areas along the coastline or excavated from borrow pits on land. Although hydraulically-dredged clay fill is cheaper than granular fill to place, it undergoes irregular settlement over a period of years, requiring higher costs for foundations and continual maintenance.

Granular fill is superior to clay or mud for foundations. Clay fill, unless allowed to stand for 4 to 5 years, usually requires piles to support building foundations. Well-placed granular fill will support foundations and utilities without piles, provided the natural foundation soils beneath the fill are not too compressible.

The choice of fill material depends upon the planned use of the new land. Small amount of landfill settlements around high-rise structures could seriously damage the massive utility and service connections. Since loads in areas used as open space or for one story buildings are much smaller, settlement is not expected to be as serious a consideration.

Clay Fill

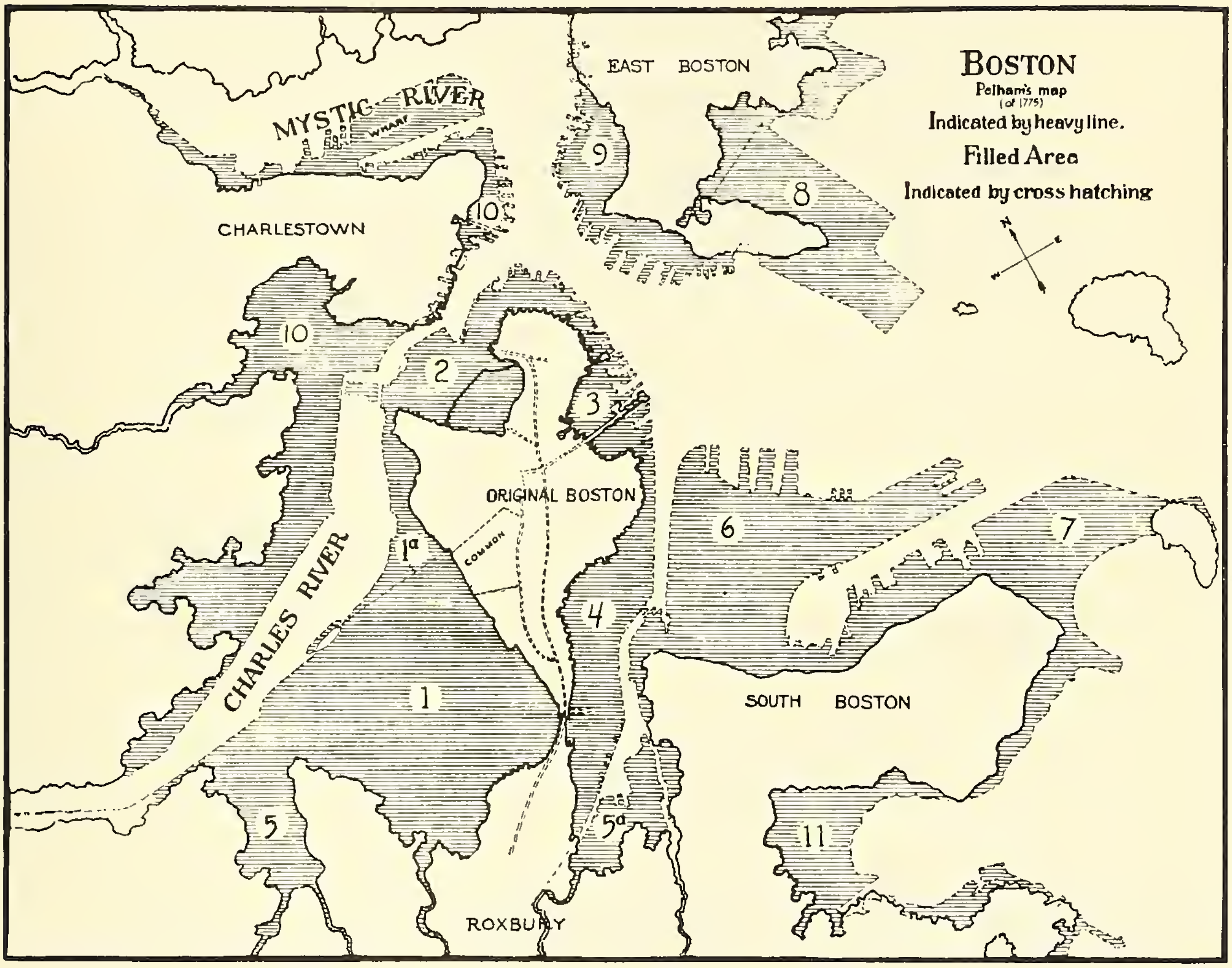
The Boston Harbor area contains sufficient quantities of clay for large landfill operations. Hydraulic clay dredging requires a pipeline supported on pontoons through which the fill material is pumped. Shipping channels cannot be crossed. When distances between the dredging site and the fill site exceed two miles, the clay is normally pumped into barges which are towed to the site and dumped. If the water at the landfill site is deep enough, the clay is directly dumped; otherwise, it is stockpiled near the site and hydraulically rehandled into position.

Granular Fill

There are no known sand and gravel deposits of significant size in Boston Harbor. U. S. Army Corps of Engineers surveys of the New England coastline show that the closest "large" sand and gravel deposits are 49 miles to the north at Cape Ann and 39 miles to the south at Plymouth. Closer borrow areas do not appear to contain sufficient material for large scale landfill projects, and are very likely to be exhausted in the near future by sand and gravel companies or used for other landfill projects.

Fill Placement

Hydraulic clay fill, placed by dredges operating either in the source areas or in stockpiles near the landfill sites, requires: that pockets of unusually soft material, must be located and removed; and the discharge of muddy water spilling out of the fill area be prevented by the construction of bulkheads or dikes and/or the operation of stilling basins. Granular fill will cause no unusual technical problems.



CHRONOLOGICAL KEY TO THE LANDFILL AREAS

1	South End and Back Bay	6	South Boston
1a	Back Bay	7	South Boston
2	West End	8	Logan Airport
3	Waterfront	9	East Boston
4	South End	10	Charlestown Navy Yard
5	Fenway	11	Columbus Park
5a	Roxbury		

NOTE: Since the time of the preparation of this map other areas (notably the Logan Airport extensions) have been filled.

Most areas of the site are covered by a thick layer of bottom mud which because it is very compressible will result in any fill placed on top of it being likely to undergo unacceptably large and uneven settlements. The mud layer must therefore be excavated before placing the fill. As mentioned above measures will be taken in the disposition of this mud in order to avoid even temporarily polluting nearby water and silting of boat channels.

Landfill Costs

The basic cost of fill material (placed in 1972 or 1973) is estimated as follows:

Hydraulic clay fill: $1.00-$1.50 per cubic yard, plus $0.25-$0.50 for a booster pump for distances greater than 3,000 feet.

Granular fill: $2.50-$3.00 per cubic yard, barged from offshore areas near Plymouth.

Out to water depths of 5 to 10 feet, the 1972-1973 cost per square foot of filled ground around the Harbor Islands is estimated to be in the range of $2.00-$3.00 per square foot for hydraulic clay or about $160,000 per acre with 25% consolidations fill, and $3.00-$4.00 per square foot for sandfill, or about $200,000 per acre. In estimating the cost per square foot of filled land, two additional figures are included: the cost of removing mud from the Harbor bottom in areas where fill is to be placed and the cost of dikes or rip rap for shoreline protection within the range of elevations affected by wave action.

Fill Elevation

The design elevation of landfill is high enough above the water to prevent flooding.

The highest tide recorded in Boston Harbor was 15 feet. Adding to this a 2 foot allowance for wave "run-up" and and additional 1 foot for the rising sea level we reach 18 feet for design elevation. Absolute protection from the simultaneous occurrence of a maximum storm tide (an additional 6 feet for 100 mph winds), a maximum wave "run-up" (about 3 feet) and another foot for the changing sea level, would require an elevation of 25 feet. The cost of additional landfill to reach this absolutely "safe" elevation is however greater than the cost of damage from occasional storm flooding, so accepted practice in the Boston area is to use the 18' figure as a design elevation.

Dikes

Dikes or retaining walls are used to increase the slope on the edge of a fill bordering a channel. The proposed Expo plan includes some narrow waterways which would not be navigable if fill were allowed to come to rest on the usual slopes of 1:20 for clay or 1:6 for sand.

There are several types of dikes in common use. Two which are planned are rock dams and concrete or steel retaining walls. Rock dikes are usually of trapezoidal cross-section with slopes ranging from 1:1 to 1:3. The top and seaward sides are faced with riprap to protect the structure from wave action. The accompanying figure shows a typical cross section with side slopes of 1:1½ and design elevation of plus 20 feet and an average water depth of 10 feet. Rock for

such a dike is expected to cost about $5 per cubic yard for quantities of half a million yards or more. At this price the rock dike shown would cost $330 per linear foot.

Retaining walls can be constructed of interlocking steel or concrete panels similar to sheet piling. Such walls will have vertical sides but will require structural bracing to hold the weight of the fill. In addition, such walls require a strong footing. Steel sheet wall this size would cost about $275 per linear foot exclusive of bracing costs. Bracing is dependent upon the configuration to be enclosed, but a reasonable estimate would be about $225 per linear foot of wall. This type of retaining structure will be backfilled only with granular fill (rather than clay) to reduce hydrostatic pressures which might lead to bending of the piling, and eventual failure of the retaining wall.

Pier Platforms

Platforms will be built and supported on piles, much the same as piers. Such platforms have several advantages over landfill, e.g., they require no dikes or riprap, are not subject to erosion or settling, and they do not interfere with tidal flow. However, they are generally much more expensive than fill. Typically, a steel and concrete platform with 25 foot spans capable of supporting buildings 10 to 15 stories high costs about $15 per square foot, exclusive of piling costs. The cost of piling for the platform with a 5-10 story building will be approximately $10 per square foot, thus the total cost is $25 per square foot. This piling provides support for utilities, foundations, first floors of buildings, and road beds for roadways, thus partially offsetting other building costs. This cost, while considerably higher than the cost per square foot for fill, is justifiable in areas where preservation of tidal flow is necessary, and in certain instances for design considerations.

Semi-Floating Platforms

These platforms will be built totally above water, connected by stilts to a totally submerged flotation tank. This configuration will yield a uniform buoyant force under all tidal configurations, and minimize the horizontal load due to wave action. The only load which will be transferred to the soil is that required to anchor the building. In addition to providing lighter, more uniform loads, this configuration permits tidal flow. This type of platform offers flexibility, in that it can actually be moved after the Exposition, and an opportunity for innovative solutions to the challenge of waterfront development. Complete cost data on this method of construction is pending.

Water Pollution

Three basic classifications have been established for water quality in estuaries and coastal waters. Class SA describes the cleanest waters, suitable for all recreational activities. Class SB describes waters that are still legally suitable for swimming and restricted shellfishing but are not entirely clean. Class SC describes waters that are not suitable for swimming or shellfishing, but are still suitable for boating and finfishing.

The water in Boston Harbor, including Dorchester Bay, is presently classified SB, although shellfishing is now prohibited. This classification is a goal set by the Massachusetts Department of Natural Resources and when this goal is achieved the harbor will be usable for swimming, finfishing and boating.

At present use of the Harbor for swimming is a "significant hazard to health" (Camp, Dresser & McKee). Pollution can be divided into three types: that from raw or partially treated sewage; that from aquatic growths, such as sea lettuce, which feed on the nutrients contained in raw

or treated sewage; and that from non-sewage sources such as oil, debris, and refuse.

Eight outlets discharge raw sewage into Dorchester Bay at this time. In addition, there are many malfunctioning combined sewage outlets. These are sewers designed to handle both sanitary sewage and storm runoff, sending both types of sewage to treatment plants. However, during heavy rains, the storm water overloads the system, and the sewers overflow, so that raw sewage spills over into harbor waters.

Within Dorchester Bay, the Moon Island sewage treatment plant is currently discharging an average of 12 to 13 million gallons daily of raw sewage through outfalls north of Moon Island. (See Figure 4). Of this amount, about 12 million gallons daily is being pumped through the Calf Pasture pumping station at Columbia Point, and 600,000 to 800,000 gallons daily is coming from Squantum Point. The Metropolitan District Commission expects to reroute the Squantum flow to the Nut Island treatment plant and the flow from Calf Pasture is to be rerouted to the Deer Island treatment plant, both by 1970.

Tidal flushing action is such that disastrous buildup of pollution from the combined sewer outlets has been avoided, and it is expected that the swimming beaches in Dorchester Bay probably will be open for bathers most of the time in summer 1969.

Camp, Dresser, McKee, Boston consulting engineers, completed a 19 month, $220,000 report to the City on improvements to the main drainage system. This report was made for the City's Public Works Department and financed partly from a grant from the U.S. Department of Housing and Urban Development (Project P-Mass-3306).

The report recommended an initial program costing $38 million to intercept those sewers discharging raw sewage into the Harbor, to treat this sewage, and to improve certain outlets and appurtenant facilities. A detailed breakdown of the cost of that portion of their plan that affects Dorchester Bay follows. The Exposition budget includes $20 million for the construction of that portion. The difference between their estimate of $16.6 million and the $20 million is taken up by inflation.

Proposed Facilities	Estimated Construction Cost*
Mt. Vernon St. Sewer Columbia Point to Columbus Park	700,000
Improvements to Outlets and Appurtenant Facilities 93-109 inclusive (Includes outlets and facilities at N St. at Day Blvd.; K St. at Marine Rd.; H St. at Marine Rd.; Rev. R. A. Burke St. below Marine Rd. and Day Blvd.; Kemp St. at Henry Sterling Sq., Murray Way at Old Colony Way, Crescent Ave., Carson and Sidney Sts.; Morriseey Blvd. and Mt. Vernon Sts; Southeast Expressway east of Freeportway at Malibu Beach; Dorchester Ave. near Hancock St. to Freeportway and Fox Point; Freeport St. at Kimball St.; Park St. near Dorchester Ave. to Sturtevant St. and Victory Rd.; Ericson St. to Port Norfolk St.; Neponset Ave.; Craddock St. and Walnut St. to Neponset Rd.; Minot St. at Granite St. to Hallet St.; Granite Ave. at New Haven RR Milton Branch.)	200,000
South Boston Pollution Control Conduit	
East Branch	4,360,000
South Branch	2,330,000
Carson Beach Pumping Station	5,000,000
South Boston Force Main	3,710,000
	$16,600,000

*1967 Dollars

The present condition of the water in Dorchester Bay is such that Expo Boston could be held at the proposed site even if no improvements were effected. Expo Boston will not adversely affect tidal flushing, and, judicious dredging and fill will eliminate beds of sea lettuce. But the Expo Corporation realizes its responsibility to the community and thus plans to implement that portion of the Camp, Dresser & McKee plan that will result in a clean Dorchester Bay.

The Exposition will dispose of its own wastes through new lines connecting into the existing sewerage system to Deer Island. This system has been found to be adequate to accept the quantities of wastes anticipated.

The second source of pollution, aquatic growths that feed on the nutrients contained in raw and treated sewage, presents a different problem. The water is robbed of the dissolved oxygen needed by fish, and beds of sea lettuce develop on tidal flats. The sea lettuce decomposes when exposed to sunlight during low tides, releasing hydrogen sulfide gas which is nauseous in odor and can discolor housepaints in adjacent shoreline communities. A solution to this problem is to dredge or fill the tidal flats; as proposed by Expo Boston.

Non-sewage pollutants such as oil, debris and refuse are difficult to control because they come from a multitude of sources. However, steps have been taken recently to control oil spillage, and this problem should become less serious in the future. In general, strict enforcement of existing laws regulating the release of debris and refuse into the harbor would measurably improve the situation. Increased public concern about the condition of harbor waters creates a favorable climate of opinion for such enforcement.

Transport of pollutants out of the harbor is essential for the maintenance of a dissolved oxygen supply in the harbor.

This transport is effected primarily by the tides; incoming tides dilute the pollutants in the harbor and the ebb tide removes substantial quantities of them.

A study by the Hydrodynamics Laboratory of M.I.T as part of their Harbor Island Study (Harbor Pollution and Harbor Development, Cross, Sy and Vicens, November, 1968) collected data on tidal flow, and the transport of pollutants, through various channels connecting Dorchester Bay, Quincy Bay, Hingham Bay, and the open sea. Soluable phosphorus, a typical nutrient found in polluted water, was the component measured. In their opinion, construction connecting Columbia Point and Thompson Island would not adversely affect tidal flushing, as long as a channel 500' in width was left open. The span incorporated in Expo Boston's proposal is over 1200' - more than twice the recommended minimum.

Aircraft Noise

The Exposition site lies south and slightly west of Logan Airport and beneath the path of aircraft landing at or taking off from one of the main runways. While it is no closer to the flight paths of the airport than many other sections of the Boston Metropolitan Area, the noise is such that some abatement measures must be taken to make the area satsifactory for Exposition and later residential use. Aircraft noise is a problem that must be faced not just on this site, but in many of our large cities with urban airports. Even those cities which began with airports far out in their rural hinterland are finding that the suburbs are rapidly spreading toward them. Thus, by directing its attention to this problem, the Expo will find solutions applicable to other parts of Boston and to other cities.

Measurement of Noise

Acoustical instruments are used to measure noise (sound pressure) received at the points of measurement. The perceived noise level, measured in decibels (PNdB), is a function of the line of sight distance to the aircraft and the noise of its engines. Since a person's sensitivity to noise varies with pitch, PNdB measurements are also a function of frequency.

The PNdB levels for a given location when weighted to account for the time of day, the volume of air traffic and the annual runway utilization, give us a composite noise rating (CNR). This is a useful measure of noise as the CNR scale closely corresponds to varying levels of human toleration.

Around Logan Airport and along the aircraft flight paths a series of contour lines have been drawn which define areas or zones of equal CNR levels. (See accompanying illustration). Within these contour intervals it is possible to judge the amount of noise inteference with normal activities.

Noise Control

There are several methods that can be used to reduce this interference. These can be divided into site considerations and building or architectural considerations. In addition, the Federal Aviation Agency is proposing legislation attacking the source of the noise by limiting the noise generated by the aircraft.

Logan Airport

Presently at Logan Airport there are approximately 300 to 350 operations per day. (An operation is defined as one landing or one takeoff). By 1975 this is expected to increase by 200%, to approximately 1000 operations per day. Presently about one-third of the total operations occur at night. (For purposes of noise studies, Day Time is the period between 7:00 A.M. and 10:00 P.M. and Night Time is the period between 10:00 P.M. and 7:00 A.M.). However, due to saturation these hours may not hold in the future. Most of the operations at Logan involve short-range, three and four engine jet airplanes. (Short-range is a destination of less than 2000 miles and long-range is a destination over 2000 miles. The noise generated on takeoff by an airplane on a long-range flight is higher than the noise generated by the same airplane on a short-range flight, due to the increased fuel load.)

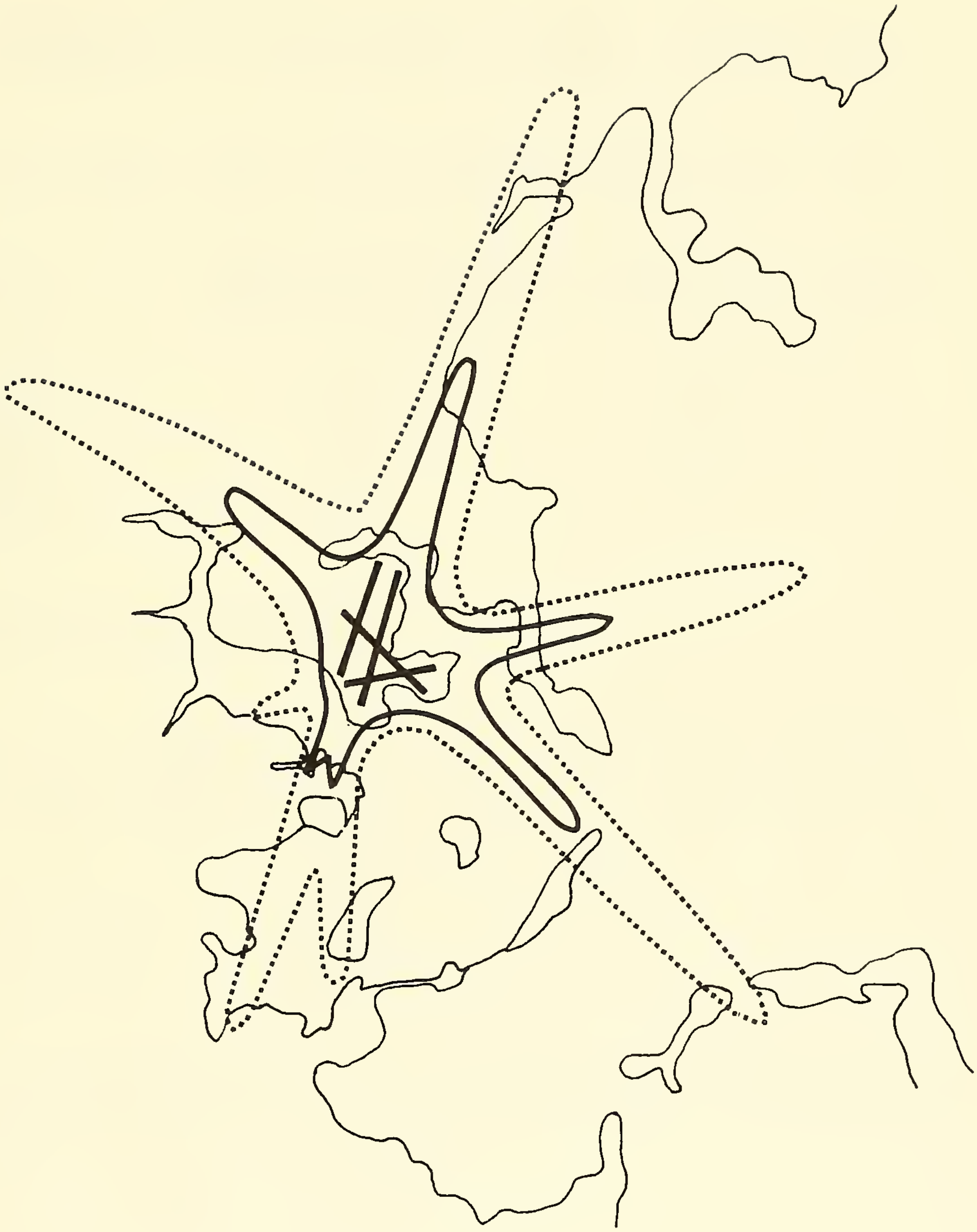
The future use of Logan Airport depends to a large extent upon whether or not other airports are developed in the Boston area. It is therefore not possible at this time to say with any degree of certainty what this use may be. One possibility is that a new airport might be built to handle international and long range flights. This type of arrangement could decrease the noise level in Dorchester Bay.

The types of airplanes that will use Logan in the future may influence the noise level there. In addition to present airplanes, the ones which are scheduled for future use are jumbo jets, airbuses, super sonic transports and vertical or short-runway planes (VSTOL). The jumbo jets and airbuses were designed to be less noisy than present day 4 engine jet aircraft. The noise levels of the VSTOL are considerably lower than those of present airplanes. Noise levels would be drastically reduced if the bulk of the operations were to be with VSTOL. On the other hand, the noise levels of the supersonic transports will be higher than those for present airplanes. But since standards and regulations as to their use have not as yet been determined, it is impossible to predict their influence on noise levels.

Site Considerations

Once noise is generated or transmitted to a given area it is difficult to completely eliminate it from that area. However, site layout is very helpful in noise control as some functions are more tolerant to high noise levels. In addition, landscaping is very important in controlling noise. It does not serve effectively as a barrier since it is not solid, but it does serve as an absorber and alternator, thereby lowering the noise level. Thus, the liberal use of landscaped areas, as opposed to hard surfaced areas (paving, concrete, etc.), will be encouraged wherever possible.

Exterior features and treatments also serve as aides to noise control. Cantilevers and projecting balconies can serve as barriers to sound sources. Broken wall areas can break-up sound waves, thereby reducing the possibility of sound concentration in certain areas. The strategic



AIRCRAFT NOISE
DAYTIME OPERATIONS

.... Zone II
——— Zone III + IV

Source: Bolt, Beranek + Newman

placement of sound absorbing materials (such as on the underside of cantilevers) can also attenuate noise.

The following table gives acceptable noise levels for various land uses, both in PNdB and CNR levels.

Activity	Acceptable Exterior Noise Levels (CNR)	Acceptable Interior Noise Level (PNdB)
Industry	110-120	80-90
Store	100	70
Office	80-95	50-60
Hotel	90	60
Residence	90	60
School	85	55

Building Considerations

If 60 db is taken to be an acceptable interior noise level for residences, the reduction in noise that must be provided for residences in each of the zones is:

Zone I:	No reduction necessary
Zone II:	10 db.
Zone III:	10-25 db.
Zone IV:	Over 25 db.

Noise reduction of 10 db. will generally be required for residentail areas at the Exposition and in the New Community.

The acoustical insulation problem does not lie in providing adequate insulation on <u>interior</u> walls and ceilings of houses. This type of insulation only absorbs noise once it gets into the house; it does not prevent sound from entering. The inherent properties (i.e. the transmission loss) of the structure itself are the best type of insulation. Most walls have an adequate transmission loss to prevent even the high amblant noise levels considered here from being critical. Windows, doors and connections provide the weakest acoustical links in the structure. This is where the greatest attention will be given.

Insulation Costs - Upper Bound (Zone I)

In general, no insulation is required in Zone I. However, it should be remembered that the noise levels in any one zone are not uniform throughout that zone, but become progessively higher as one approaches the next higher zone. Thus, those parts of Zone I which are adjacent to Zone II areas will be nearly as noisy as Zone II. Thus, in some Zone I areas, it may be desirable to keep doors and windows closed to help "shut out" noise. In these areas air conditioning may be desirable.

Two types of air conditioning units seem to be the most reasonable for use in apartments. The first is the individual unit placed in an exterior wall. This unit eliminates the need for a central AC system and attendant piping but still provides heating, cooling and air exchange. It occupies the least building volume, making it particularly attractive in small apartment buildings. Its main drawback is its excessive noise (up to 55 db.) which may augment the aircraft noise. The cost of such a unit is about $1.80/square foot.

The second type of air conditioning unit which is favorable in housing is the "fan-coil system". This is a central system but is not as expensive to install and operate as other central systems. The equipment may be installed so it becomes part of the interior space and is easily fitted into place. The cost of this unit is about $1.60/square foot. An average cost of $1.70/ft for air conditioning will be used for cost estimates.

To compute the <u>increase</u> in cost due to the installation of air conditioning units, the cost of a conventional heating unit ($0.55/ft) must be subtracted from the cost of air conditioning. Thus, the increase in cost due to air conditioning is $1.15/ft. This is the only increase in cost due to acoustical insulation in Zone I.

In Zone II a noise reduction of 10 db. is necessary. Double windows must be used, consisting of ¼" glass in resiliant gaskets, a 4" air space, and ¼" glass in resiliant gaskets. These windows cost $6.30/ft of window area. Hence the total cost of the windows is:

$6.30/ft x 56 ft = $350

The cost/ft of room area is:

$350/(12' x 30') = $0.98/ft

For conventional windows, the cost/ft of room area is:

$95/(12' x 30') = $0.26/ft

The cost increase for providing double windows is:

$0.72/ft

To provide a noise reduction of 10 db. conventional doors may be used if new heavy-duty weather-stripping is added. This costs $17/door or:

$0.05/ft

Again the windows must be kept closed in this Zone so the increase in cost due to air conditioning must be added. The total cost increase for the Zone is:

$ .72
.05
1.15
$1.92/ft

Insulation Costs - Lower Bound

A lower limit on the cost of insulation may be found by assuming a more favorable module configuration with the modules fitted into a multistory megastructure. These modules have one 6' x 4' and one 4' x 4' window and no access to the exterior directly. The estimated cost of insulating such a module follows.

(Zone I): The insulation required in this case is the same as that found previously. Windows must be kept closed, necessitating the use of air conditioning. Thus, the increase of cost due to acoustical insulation is $1.15/ft.

(Zone II): Double windows are used in this Zone adding a cost of $6.30/ft of window area. The total cost of windows becomes:

$6.30/ft x 40 ft = $252

The cost/ft of room area is:

$252/(12 x 30) = $0.70/ft

For conventional windows, the cost/ft of room area is:

$70/(12 x 30) = $0.20/ft

The cost increase for providing double windows is:

$0.50/ft

The total cost increase now becomes:

$0.50
1.15
$1.65/ft

From these two extreme cases, the limits of the cost increase can be determined. These are:

Zone I: $1.15/ft
Zone II: $1.65-$1.92/ft

Recent construction costs for 221(d)3 housing in Boston have been in the range of $11 to $14 per square foot. Thus, noise insulation is expected to add about 15% to housing of similar cost in Zone II.

Noise Leaks

The best sound insulation will have negligible effect if noise leaks occur. The perimeters of doors and windows, wall joints and connections are areas that can be particularly susceptible to noise leaks.

Since any exterior opening in a building is a potential noise leak, great care must be given to the design and location of ventilators, air intakes, etc., which must be open to the exterior of the building. It is possible to provide sound baffles in much the same way that light can be stopped through the use of baffles. (However, careful design is needed to avoid creation of resonating cavities.) During the construction phase close supervision of the work is a must. Improper or sloppy installation of components can completely negate an acoustically well-designed building.

Good acoustical design involves the careful planning of room layout to isolate noise sensitive functions from exterior noises and interior noises. Rooms or areas of equal noise tolerances should be grouped together if possible. Furthermore, rooms that have higher noise tolerances such as kitchens, storage areas, closets, bathrooms, mechanical rooms, stairways, etc., can be located so as to serve as buffer zones for the more critical rooms such as bedrooms and living rooms.

In some cases it will be perhaps technically or economically unfeasible to completely reduce the level of noise entering a building to the acceptable interior level. Since the annoyance level of a noise is related to duration it is desirable to dissipate the noise entering the room (as well as noise generated in the room) as quickly as possible. This can be accomplished by the use of sound absorptive materials (carpets, rugs, acoustical tile ceilings, fabric covered furniture, even people within the room. It must be stressed that this method is not a substitute for good sound insulation techniques.

Noise Standards

On January 11, 1969 the Federal Aviation Administration issued a notice of proposed legislation regarding the noise generated by subsonic transport category airplanes and subsonic turbojet powered airplanes. In this notice the FAA has proposed maximum noise levels at certain distances from an airport. The unit of noise level that is used in this notice is the Effective Perceived Noise Level. A correction factor to account for pure tone content is added to the Perceived Noise Levels to obtain the Effective Perceived Noise Level. The EPNL is roughly 3 to 10 db higher than the PNL, and is considered to be a better indication of the annoyance caused by airplane noise than is PNL. The result of this noise standard as applied to Logan Airport and the Dorchester Bay has been analyzed and does not alter this report.

It should be noted that this proposal is extremely lenient, and in fact is currently met by most aircraft operating in the area. In addition, this proposal measures the actual noise and tone spectrum of the noise, but is not weighted for number of flights, time of day, etc., which are considered in CNR. However, strict enforcement of these regulations might encourage pilots to follow prescribed takeoff and approach patterns, confining annoyance to a smaller area.